NORTH ATLANTIC TREATY ORGANISATION

RESEARCH AND TECHNOLOGY ORGANISATION

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RTO TECHNICAL REPORT **TR-IST-028**

Coalition Information Interoperability

(Interopérabilité d'informations de coalition)

Final Report of the Task Group IST-028/RTG-010.

Published December 2008

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The Research and Technology Organisation (RTO) of NATO

RTO is the single focus in NATO for Defence Research and Technology activities. Its mission is to conduct and promote co-operative research and information exchange. The objective is to support the development and effective use of national defence research and technology and to meet the military needs of the Alliance, to maintain a technological lead, and to provide advice to NATO and national decision makers. The RTO performs its mission with the support of an extensive network of national experts. It also ensures effective co-ordination with other NATO bodies involved in R&T activities.

RTO reports both to the Military Committee of NATO and to the Conference of National Armament Directors. It comprises a Research and Technology Board (RTB) as the highest level of national representation and the Research and Technology Agency (RTA), a dedicated staff with its headquarters in Neuilly, near Paris, France. In order to facilitate contacts with the military users and other NATO activities, a small part of the RTA staff is located in NATO Headquarters in Brussels. The Brussels staff also co-ordinates RTO's co-operation with nations in Middle and Eastern Europe, to which RTO attaches particular importance especially as working together in the field of research is one of the more promising areas of co-operation.

The total spectrum of R&T activities is covered by the following 7 bodies:

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These bodies are made up of national representatives as well as generally recognised 'world class' scientists. They also provide a communication link to military users and other NATO bodies. RTO's scientific and technological work is carried out by Technical Teams, created for specific activities and with a specific duration. Such Technical Teams can organise workshops, symposia, field trials, lecture series and training courses. An important function of these Technical Teams is to ensure the continuity of the expert networks.

RTO builds upon earlier co-operation in defence research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defence Research Group (DRG). AGARD and the DRG share common roots in that they were both established at the initiative of Dr Theodore von Kármán, a leading aerospace scientist, who early on recognised the importance of scientific support for the Allied Armed Forces. RTO is capitalising on these common roots in order to provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

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Table of Contents

List of Figures

Foreword

In 2001, the Information Systems Technology (IST) Panel of the NATO Research and Technology Organisation (RTO) established the Task Group on Coalition Information Exchange. The objectives of the TG were to establish the basics of an interoperability strategy for NATO coalition operations in three time frames: short; medium; long term.

While recognising that providing the full spectrum of interoperability needs is well beyond the resources of a working group, this group could provide the key pointers for both short-term and long-term demonstrations of specific interoperability needs. Some main goals of this work were to identify and describe solutions for some key interoperability problems that are important in the longer term and to show that some of these solutions were practicable by means of demonstration, simulation or modelling as appropriate.

During its lifetime the TG has published several papers and a Workshop Proceedings, as well as making contributions to the NATO IST Symposium of September 2004.

The work of the TG has taken place over a period of three years.

This report has been written as a joint effort by the members of the TG during meetings and direct interaction.

Ian White

Chairman of the Task Group

Acknowledgements

The Task Group (TG) member list (December 2004) is provided on the following page. All TG members have contributed to the background for this report, and all former members are thanked for their efforts in contributing to the work of this TG.

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Coalition Information Interoperability

(RTO-TR-IST-028)

Executive Summary

The Task Group (TG) on Coalition Information Interoperability has focused on two themes:

- Representing information situation in terms of an ontology; and
- Representing information in the form of large data models.

As communications networks increasingly providing extensive and rapid interconnection of a wide range of personnel within the military and civil organisations, there is a huge growth in the potential, and the reality of information exchange. In effect a new social structure for an information society is needed that has established practices for information communication, information management and control. This growth, exemplified by the World Wide Web's phenomenal success has caused a corresponding increase in research into information management. Despite the widespread recognition of this need in the civilian world, again demonstrated by the World Wide Web Consortium's Semantic Web Programme, there has not been the same sense of urgency about the need to gain control of this issue in the military domain, especially in an Allied or coalition context.

In a small NATO Task Group the scope of any inquiry into the issues posed by this problem must necessarily be constrained, hence the two focus points cited above. Each of these is concerned with ways in which information is organised, rather than how it is moved between data depositories and users, or how it is managed from a data \ life cycle point of view. These are important aspects of information management.

This final report of the TG has general conclusions, recommendations and lessons learned, that apply to both themes. The two themes are described in more detail, in the text and in accompanying references reports.

Interopérabilité d'informations de coalition

(RTO-TR-IST-028)

Synthèse

Le Groupe Opérationnel (TG) sur l'Interopérabilité de l'information de coalition s'est intéressé à deux thèmes :

- La représentation de la situation de l'information du point de vue de l'ontologie ; et
- La représentation de l'information sous la forme d'importants modèles de données.

Les réseaux de communication fournissant de plus en plus une interconnexion étendue et rapide avec un grand nombre de personnels dans les organismes civils et militaires, on observe une énorme progression réelle et potentielle des échanges d'informations. En effet, le besoin d'une nouvelle structure sociale pour une société de l'information a instauré des pratiques de la communication de l'information, de la gestion et du contrôle de l'information. Cette croissance, illustrée par le succès phénoménal du World Wide Web, a provoqué une augmentation correspondante de la recherche sur la gestion de l'information. Malgré la reconnaissance générale de ce besoin dans le monde civil, dont le Programme Sémantique du Web du Consortium World Wide Web en est un exemple, il n'y a pas eu le même besoin urgent de prendre le contrôle de ce problème dans le domaine militaire, en particulier dans un contexte Allié ou de coalition.

Dans un petit Groupe Opérationnel de l'OTAN, l'objet de chaque enquête sur les questions posées par ce problème doit nécessairement être limité, d'où les deux points d'intérêts cités ci-dessus. Chacun de ces points d'intérêts concerne plus la façon dont l'information est organisée que la manière dont elle est amenée de la banque de données à l'utilisateur ou la façon dont elle est gérée du point de vue du cycle de vie des données. Ce sont des aspects importants de la gestion de l'information.

Ce rapport final du TG apporte des conclusions générales, des recommandations et des enseignements tirés qui s'appliquent à deux thèmes. Les deux thèmes sont décrits en détail dans le texte et dans les rapports de références qui les accompagnent.

Chapter 1 – INTRODUCTION

1.1 BACKGROUND

1.1.1 The Information Management Requirement

The need for information interoperability across coalitions is unchallenged, but how it is achieved, remains a major open question. To examine this issue further the NATO IST Panel supported the formation of a Task Group on the topic title to examine this issue, and to make recommendations on potential ways forward. The Group examined two related 'threads' in information interoperability – **information exchange architectures** and **ontologies**. Both relate to extant work within NATO on data modelling, and on the NATO Technical Architecture. In this paper commentaries on key issues examined by the TG within each of these two threads are described and outstanding issues are presented.

The information interoperability task within a large command control and consultation organisation such as NATO is anticipated a participating in future operations is a very challenging problem.

1.1.2 Problems

The problems for information management and exchange, within NATO (and many other organisations) are:

- Huge growth in information sources and types
- Huge growth in connectivity and required bandwidths
- Growth in user diversity – NATO is still growing – now 19 nations
- Warfare roles and participants changing

but

- There is no strong (or agreed) understanding of information representation, exchange, or management principles
- We are still struggling with information concepts

In one sense the problem is so vast, that it might be asked what can any small group of investigators contribute to it? However with members who have experience of traditional architecture models, and the problems of developing large data models, and others with knowledge of ontologies, WWW developments, and the military environment, it was felt that a useful input to the assessment of the military worth of these developments was possible.

1.2 PURPOSE, CHARTER, AND SCOPE

1.2.1 Purpose

The NATO RTO IST Task Group 010 – *Coalition Information Interoperability*, formed in January 2002, and concluding December 2004, has been examining the architectures and the emergent techniques for meeting this challenge. This final report is a summary of the major conclusions from that activity.

1.2.2 Charter

Objectives of the Task Group have been:

- To better understand how to improve information interoperability across coalition forces;
- To highlight key commercial technologies and techniques that could support future information interoperability;
- To keep the methods simple and thus widely applicable and flexible;
- To better understand the complexity/scaling implications of extending interoperability (for example in the Network Centric Warfare (NCW) / Network Enabled Capability (NEC) settings; and
- To identify sets of tools that are useful for the longer term, and to identify gaps in capability.

1.2.3 Scope

The group's approach to the problem has been to examine two parallel, but inter-related, themes:

a) Information Exchange Architectures; and

b) Data Models and Ontologies.

The first represents the top-level schema for interoperability, the second the choice of interoperability representations that such a schema should employ. This paper presents the Group's collective view, and includes results and conclusions from a workshop on the title topic help in Paris in November 2003 [1].

1.2.4 Assumptions

Although communications is important in achieving Coalition Information Interoperability, it was not addressed by this group. Communications were considered as a set of fixed parameters in order to better understand the implications of other topics of interest within the context of this group.

It was also assumed:

- That most 'systems' forming an information exchange domain[1] will be heterogeneous. Thus information exchange solutions **must naturally cope** with heterogeneity. Homogeneous information systems are most unlikely across a coalition.
- That systems will have different procurement and operational time-scales according to national priorities.
- That systems, and information exchange needs will be application domain related, e.g. to the military threat, to new forms of warfare, and to the supporting information and communications services.

1.3 ACTIVITIES, METHOD, AND DELIVERABLES OVERVIEW

1.3.1 Activities

The activities of the group were defined by an early work plan in which a number of PROBLEMS were posed by the TG and then, as far as available information and knowledge could, these questions were answered. It was all along the TG plan to bring this question list to a degree of maturity, such that it could form the agenda of a workshop held towards the end of the YG lifetime, and that the outputs of the workshop itself, would help provide input for an IST Symposium, based on a similar topic to the TG title.

[1] We assume a number of heterogeneous systems being interconnected to form a larger information domain. This will create new information exchange demands, and impose new constraints on how the information is to be used, and how it might be interpreted by its users.

1.3.2 Method

Under the heading of information exchange architectures the TG examined in workshop, and off-line investigations:

A1: Information interoperability domains;

A2: Multiple exchange mechanisms; and

A3: Ad hoc interoperability.

Under the heading Ontologies the TG examined:

O1: Developments beyond 'traditional' data models;

O2: Harmonisation and transformation of ontologies; and

O3: Tools and techniques.

We still need to better understand:

- The practical scope;
- Complexity of architecture, data model and ontology schemas [the scaling problem];
- Limitations of ontologies; and
- The relative roles of ontology and data models – these are not conflicting models – the former is a natural development of the other.

Beyond these options we have examined information interoperability in terms of two related threads:

1) Information Exchange Architectures; and
2) Ontologies.

1.3.3 Deliverables

It was decided early into the TG's work that co-operative experimental work was not feasible. The primary deliverables therefore have been reports, and the interchanges promoted by two conference style activities:

1) A Workshop in Paris in November 2003; and
2) Contributions to, and influence on the style, the NATO IST Symposium on *Coalition C4ISR Architectures and Information Exchange Capabilities.*

In addition the TG has produced a *History CD*, which gives all meeting minutes, report of the Paris workshop, and various papers submitted by members of the TG during its operation.

1.4 REPORT ORGANISATION

In Chapter 2 of this report describes data model structure and the issues and questions to be answered in establishing an architecture for information exchange. Much of this discussion is framed in the form of questions, and where available, answers. The chapter concludes with a short outline of ad hoc interoperability solutions. These were not studies in any depth, but are mentioned because it is possible to achieve a considerable degree of interoperability using some of these simple solutions.

Chapter 3 describes the potential benefits of using an ontology approach, and some of the current problems that probably only an ontology approach will be able to provide some degree of solution for.

Chapter 4 summarises lessons learned, and Chapter 5 makes recommendations for follow-on work on the important topic of information interoperability.

Chapter 2 – INFORMATION EXCHANGE ARCHITECTURES

2.1 THE INTEROPERABILITY PROBLEM AND DOMAINS

The TG restricted its concerns to NATO interoperability – that is to describe what is needed between different domains (function, and/or ownership) for them to effectively inter-operate. It does not necessarily require that each domain itself has to be completely understood. Each component system does not necessarily have to share **all** its information with other systems.[1] What is needed is a careful bounding of the interchanges needed to facilitate successful interoperability.

Secondly there is a degree of difference between interoperability in terms of access, for example via a web portal, -v- a fully interoperable schema, such as a 'common interoperability ontology', appropriately populated.

The simplest interoperability model is one in which all domains simply do their own thing, and interoperability gateways are developed as needed. This is generally considered to be an extreme view for interoperability solutions. The alternative view is to have one globally applicable interoperability exchange language. An interactive natural language understanding (NLU) interface would be ideal for this purpose, but NLU is not sufficiently understood to achieve this. Military messaging systems, data models, and now ontologies are attempts to provide the appropriate and increasingly powerful interchange languages.

Apart from the fundamental question of representational adequacy, other issues raised by the growth of information sources include:

- Control of information bases;
- Standardisation of exchange processes;
- Management [volume, direction, archiving, etc.];
- How to maintain Consistency; and
- Reasoning and exploitation of related information sources.

Trends: The results emerging from various laboratories, and organisations, notably the WWW consortium, are indicating a new revolution in information use, exchange and management. It is a revolution that the military need to exploit. Whilst evidently much of the baseline technology for this will emerge as part of commercial practice, the deeper insights into the military domain that are needed to complement this, must come from military investment directly.

2.2 QUESTIONS

In this section a number of key questions are posed and to different degrees answered. This follows the agenda that was agreed within the TG as part of its work plan.

Should the systems talk directly or should there be an interface, or a third party, which does the mediation job for both parties?

Exchanging data and information as 'objects' is technically easily. However the languages are difficult to match because of different definitions interpretations and different contexts.

Should the interface be a NATO asset or a national asset?

Any NATO asset would depend from a central controlling authority. Standardisation management and the absence of any agreed information exchange language are problems.

[1] This basic systems design principle was long ago enunciated for software design by Parnas.

What configuration control is needed?

Configuration control is essential for two parties to talk to each other. This is a well-known problem and is normally included in the early phases of new systems. The problem is to communicate without agreeing on a wide ranging, common fixed standard, but one that might for example be agreed every three years.

What is the role of Interoperability Testing?

Standards are not enough to have interoperable systems. Planning and testing systems together is generally useful. JWID is a good example of exploratory interoperability testing: JWID demonstration systems are increasingly interoperable, and have some success in application follow-through. The MIP also does interoperability testing every 2 years to assess the efficiency and performance of its MIP solution.

2.3 INFORMATION INTEROPERABILITY DOMAINS

To reach overall system interoperability within NATO, a single 'Esperanto' is not believed to be a sensible goal. An all-embracing information exchange standard is unlikely to solve the interoperability problem, because it will be:

- Too large;
- Its complexity and scaling properties are unlikely to be understandable, even empirically by a sufficient number of people; and
- Through-life management will be too extensive to sustain.

An alternative approach is to have smaller 'information domains', tightly identified with military areas of expertise, operation, or organisation. An inevitable consequence is multiple "exchange languages", each serving a specific "interoperability domain". Therefore some sort of *"NATO C3 domain structure"* is needed to facilitate interoperability *between* these domains. A short information analysis has resulted in a possible domain structure for NATO, consisting of 17 domains that more or less cover the area of coalition C3 information exchange (Figure 1) [2].

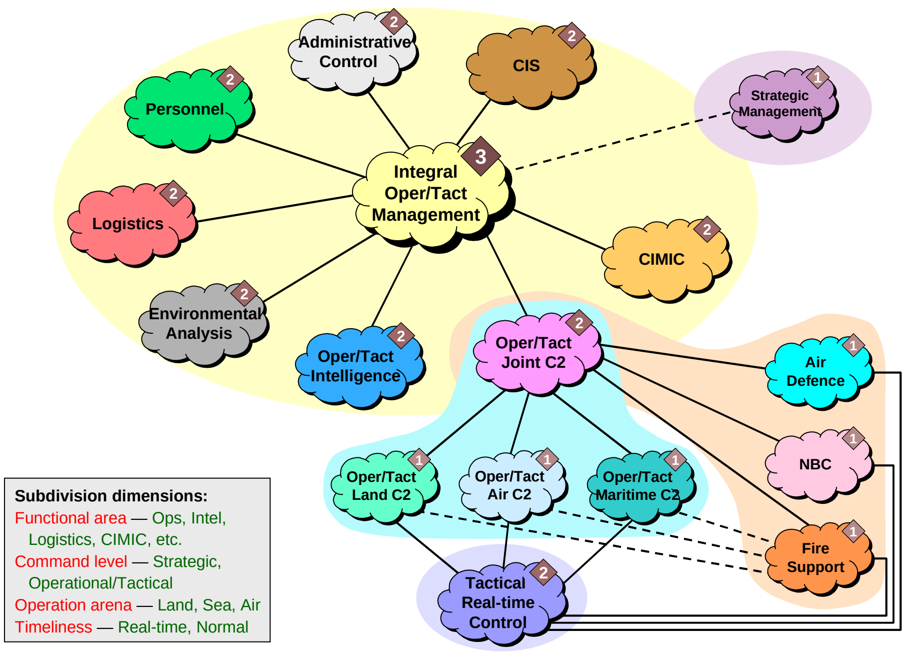

Figure 1: Proposed NATO Domain Structure.

NATO would have to co-ordinate the development of these discrete domains, prescribing the scope of their information standards (exchange languages), but not developing them.

Current information exchange programmes within NATO (e.g., Bi-SC AIS, NATO Corporate Data Model, MIP) should evolve in such a way they will grow towards such a domain structure.

Although this domain structure is reasonable in the TG's opinion, we need military Domain Experts first to help agree domain partitions, and secondly to develop a domain management infrastructure, covering aspects such as:

- Agreed Description;
- Domain structure;
- Simplified DMs;
- Overarching description; and
- Analysis of the value of different methods.

Important factors are:

- Relationships between domains;
- Dependencies; and
- Evolution.

2.4 MULTIPLE EXCHANGE MECHANISMS BETWEEN DOMAINS

Overall interoperability within NATO requires *multiple* exchange mechanisms, which can be used *interchangeably*. The principle is shown in Figure 2.

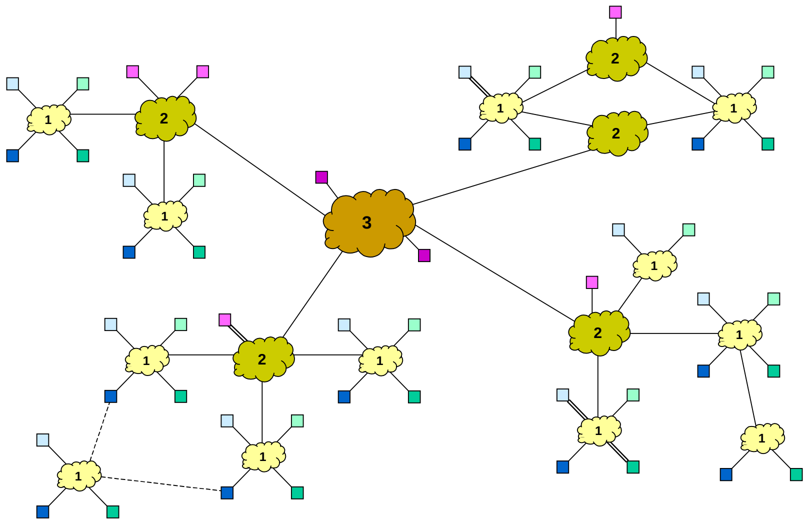

Figure 2: Hierarchy of Mediation Levels[2].

Some kind of 'layered' information exchange protocols (on top of some communication layer protocols) are needed that enables the seamless and simultaneous usage of different exchange mechanisms. This is

[2] From E. Lasschuyt.

shown in the figure, in which level-2 'clouds' are the mediators at that level, and 'cloud-3' mediates at the higher level.

No matter what exchange mechanism is selected, the *same* information standard should be used when two systems exchange information.

The process element of any integrated protocol for information exchange could be:

1) Web-based exchange (using portals, web services);

2) Exchange of XML-formatted messages (via e-mail);

3) Automatic exchange of XML-formatted messages (using some simple protocol); and

4) Automated database-to-database transfer (using replication or publish-and-subscribe mechanisms).[3]

Although the exchange mechanisms mentioned here are primarily meant to distribute *structured* information, it should also be possible to incorporate *unstructured* information (embed it in the structured information). In that way it can be exchanged by the same mechanisms. A fuller discussion of these issues is given in [2].

2.5 MODELS FOR INTEROPERABILITY

2.5.1 Questions

The favoured exchange method to date has been based on the use of data models, (and may perhaps in the future be based on ontology models) if these up to the task?

What are the limits of data models?

Data models are widely used as the foundations of ontology models, but we need to better understand the complexity issues of such models (how long to develop, maintain, relate model size to features of the domain etc.).

A data model is, in effect, means to capture part of an ontology, i.e. not as richly descriptive and not allowing computer 'reasoning'[4]. This appears to imply that an ontology will always be more complex than a data model for a given problem. The increased complexity in this case should solve some problems that the source data model itself could not compute/perform, but the complexity of such solutions is likely to be comparable.

Is the complexity of NATO's JC3IEDM overstated?

The NATO *Joint C3 Information Exchange Data Model* (JC3IEDM [3] development started in the 1980's with the ATCCIS Study, when no good tools, no mature web concepts, let alone ontology tools existed. Now, after 24 years, the ATCCIS Model has developed to a much wider ranging ambition for a joint C3 model, the JC3IEDM, which is being developed by the *Multilateral Interoperability Programme* (MIP). The MIP programme is supported by over 20 countries and other organisations, and therefore is positioned to play a substantial role in information interoperability. Do we think it can be done much more efficiently now, and if so how much more efficiently? The answer is that it would be more efficient now, but by what factor is difficult to say. Related questions are:

- *Do we understand the scalability of these models?*

[3] There are other forms of information exchange, for instance using cell phones, chat boxes or informal e-mail as a basic primitive, but these fall outside our scope of information interoperability.

[4] The distinctions are explained in more detail later in this paper.

- *Do we really understand the maintenance cost [as opposed to the creating cost]?*
- *How is flexibility/evolution handled?*
- *Would an OWL version of a DM be better able to handle these aspects and if so why?*

At the moment the answers to these questions must await further experience.

Are ontologies any better with poorly structured information?

They could be better than a DM because of their (potentially) more powerful range of constructs, based on the use of Web standards, mentioned later in section 3, including the latter's ability to support predicate logic based reasoning about the information.

There are various potential methods for facilitating the development of data models:

- The flexibility and readability of data models can be enhanced by using a mixture of generic and specific data structures.
- Translation between different data models can be simplified considerably by making use of a small common "data model framework", i.e. a 'core' data structure that predefines the most common and basic data elements for the NATO C3 area. This framework is different from the current NATO JC3IEDM, and has analogy with the various civil sector initiatives to define 'upper level ontologies'.
- Unstructured information can **and should** be easily embedded in structured information.

2.5.2 Limited Abilities of Data Models

These include:

- *Scope*: what aspect has to be modeled and which ones have to be rolled out into specific systems covering special domains only?
- *Handling*: the bigger the application domain the better for interoperability, but the worse for maintenance, and overall comprehension.
- *Competence*: who is responsible-for / competent-to resolve conflicts?
- *Flexibility- evolution*: if new situations are mapped to new data model versions – who adapts the existing application systems?
- Data Models cannot handle weakly or arbitrarily structured information. Thus some means of incorporating unstructured information into the data model formats will always be needed.

2.6 AD HOC INTEROPERABILITY

2.6.1 Background

The TG also briefly considered ad hoc interoperability solutions. **Concept:** Coalition operations of today require an 'ad-hoc' way of interconnecting with the systems of unexpected external parties (like non-NATO nations and NGOs). Ad hoc interoperability is an attempt to define in the first place the lowest common denominators (LCD) needed for a basic level of interoperability between very different organisations.

Lowest Common Denominator Solution: At the lower communications layers it assumes adoption of standard established communications protocols, notably ISDN, IP, for mobility UMTS and related mobile

telecommunications standards, and for local connectivity the emergent standards of IEEE-802.11 and Bluetooth.

At the middleware level it assumes adoption of well established and easily obtained systems and software, notably but not exclusively, Microsoft, Oracle.

At the information level it seeks simple interchange methods:

- Formatted messages
- Standard file exchange capabilities [e.g. via FTP]
- Standard sub-set of file formats:
  - Word, RTF
  - JPG, TIFF
  - MPG, Mov
  - ASCII File
  - Screen scraping

'Intelligent' Ad Hoc Networking: Whilst the LCD approach to Ad-hoc interoperability is a start, a much more adaptive interoperability capability is really what is needed. This is one that can deal with diverse systems that use different information exchange mechanisms and offer/require differently structured (or even unknown) kinds of information. In addition, 'ad-hoc' implies system interoperability should be realised simply and quickly.

Technology and products that enables solutions for ad-hoc interoperability are becoming available but need to be further researched and developed. For example interoperability described using ontologies supporting elementary reasoning, could be used to determine best routes to interoperation, by determining feasible common interconnection processes.

Ad-hoc interoperability especially requires the underlying information standards (data models) to be more flexible than is currently the case, so that new types of information can be added to the existing structure without extant data.

We believe these aspects of interoperability are worthy of further study, and that there are some interesting and potentially very valuable methods for achieving ad hoc interoperability.

Chapter 3 – THREAD-2: ONTOLOGIES

3.1 BACKGROUND

3.1.1 What is an Ontology?

An ontology is a framework for ideas describing some coherent domain of operation or process – these ideas must come from domain specialists who understand both the domain, and what a particular system for which an ontology is needed **is expected to do**. A pertinent example is the set of four NATO levels of interoperability; these are collectively a semantic concept:

- Connected;
- Shared information;
- Shared awareness; and
- Co-ordinated action.

Ontologies are really a more logically structured form of data model, inasmuch as they have somewhat richer set theoretic definitions, with various inheritance and other relationships possible. These definitions are controlled such that there are strong constraints on definitions in order to maintain consistency. A further important feature is that ontologies normally support some degree of computer-based reasoning about the objects they describe. Such reasoning is based on first order predicate logic, and exploits various developments in this area over the last decade. It should be noted that most ontologies in use appear to have started with some legacy data model. This was then cast into an ONTOLOGY FORMAT, currently of course the new WWW consortium standard, OWL [4], and this then permitted the model to be expanded. It is entirely dependant upon the proposed applications for the data model whether this translation process is either effective or necessary. Each case must be assessed on its requirements.

The position of ontologies in a layered view of system description capability is well described by the WWW's layer diagram of Figure 3 [5]. The lowest layer represents the communications via an agreed addressing schema; *XML* etc represents a first level markup of data to facilitate its use; *RDFschema* provides a structured way of describing relationships. This level corresponds approximately to that achieved by many data model. Whilst data models can well describe essentially static structure and relationships, usually with a strong set theoretic flavor, they fail to completely capture the semantic and dynamic aspects. The ontology layer seeks to complete this capture. The logic and proof layers represent the ability to reason about the information, and the trust level covers issues of authentication and safety.

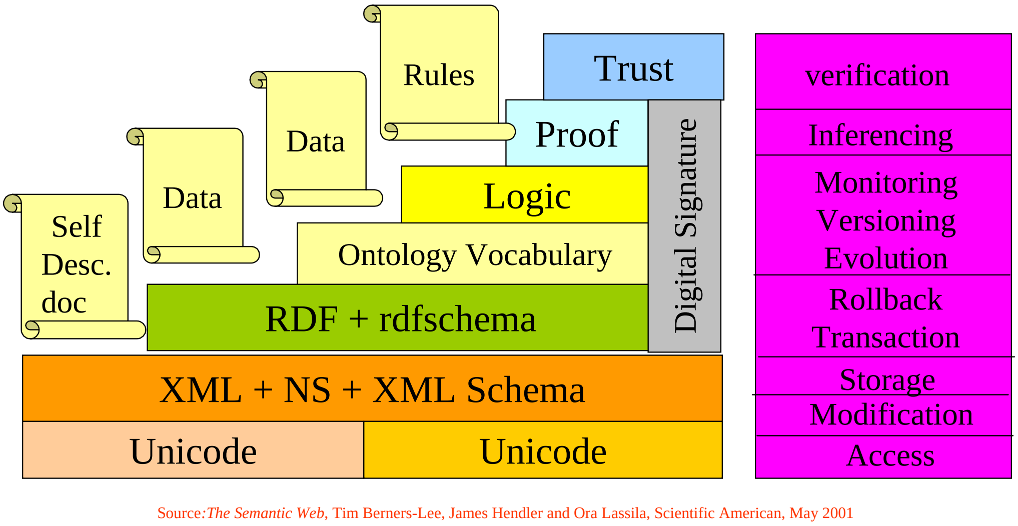

Figure 3: Ontology Layer Diagram.

New warfare management initiatives (e.g. NCW) imply very significant increases in the ability to manage and exchange information. This relates directly to interoperability capability and has been stated by Alberts thus: *"The levels of network-centric capability defined in the NCW maturity model directly correspond to the degree to which interoperability has been achieved"* [6].

The 'modern' ontology development programme, originating in the WWW Consortium's ambitions for an 'intelligent' Web is the prime contender to investigate such extensions. If we accept that a semantic component is essential for information exchange in an NCW setting, then the exploitation of available Semantic Web technologies is essential for improving coalition interoperability. The primary differences between a DM and an ontology are that:

- The semantic representation of an ontology is richer; and
- The ontology permits a more powerful range of reasoning to be conducted on the information it represents.

There should be no special problems in representing a DM in the representations used by the current ontology proponents. The *Resource Description Framework* (RDF) appears to be well structured to cover the typical definitions and relationships used by DMs. The conclusion is that large and expensive though some data models may often be, don't throw then away – they are the foundations of most ontologies!

These comments still leave us with the argument that ontologies are perhaps the upper class of DMs, but so what? How are they going to make military interoperability easier, or better? That is still only a partly answered question.

Ontologies are meant to capture the semantics of a domain – to encapsulate what things in that domain **mean**. It must be understood that this is largely achieved by a structured form of object marking, and the names of the marks can be implied as adding semantic value. Such schemas can be used as the basis for much cleverer searches, or cleverer reasoning than with a DM, but the ultimate meaning of all objects and their relationships is for human interpretation. The computer enacting an ontology process is still supremely stupid. In developing this semantic aspect there are a number of significant questions, some of which the group has addressed.

3.2 QUESTIONS

3.2.1 The Semantics of Interoperability

Questions on Semantics

Can we capture the semantics of new military concepts (e.g. NCW, NEC[1]) in such a way that there is an overall understanding of what the problem really means?

There is no simple answer. The real answer is to take at least part of these problems, and to seek to create a working ontology, and assess it by peer review.

What is the role of use-cases in establishing an embryo ontology? Do we even think this can be done in a rich enterprise process, when the best tool – OWL does not encompass modelling dynamic processes adequately?

This is an area for further research and development. There is clearly a need at some stage to enable ontologies to embrace the concept of embedded models.

Can we determine a subset of semantic relations that are sufficient for military operations?

Are there any accepted methods of testing an ontology across peer groups? This is the old AI chestnut, where the proponents judged and announced their own successes, often misleadingly.

If we allow a number of different systems supported by their private ontologies, say all in OWL, how do we scope the difficulty of the harmonisation problem?

Harmonisation is still an ad hoc process. Again the best way of answering this question is by an increased research investment in examining real problems. The favoured approach is to take a set of problems/ domains that are not too large, and not too simplistic.

3.3 WHY SEMANTICS?

Despite the developmental state of ontologies, there are strong reasons for investigating their use in military interoperability. Ontologies can:

- Include an ‘explanation component’, making data processing more flexible and easier for humans to accept. Ontologies can also handle fuzzy and unstructured information;
- Help in the representation and understanding of natural language;
- Assist in the understanding of structured information (from an unknown data model) as part of the information exchange process; and
- Mediate over various national ontologies that will occur in the near term.

Experiences are already available: Is it possible to learn from other domains (e.g. biology, medicine, seismology).

Are ontology tools sufficiently mature to be useful?

Useful tools and technologies now exist to support ontologies and semantic markup. Furthermore a new generation of tools are anticipated from the research laboratories from 2004 onwards [7]. Their utility to the (military) user needs to be demonstrated actively – how can this best be achieved? A more compete discussion of some of these issues is given in [8].

[1] NEC = Network Centric Warfare; NCW = Network Enabled Warfare.

3.4 STATUS OF ONTOLOGIES

Ontology systems are now being deployed – they work, people are using them, and they are economically supported. A US example is the National Cancer Institute ontology, which comprises thousands of entries, and is human driven, with a team of about 10 full time staff, who keep the ontology up to date [9]. Current ontology applications are generally in the data search, cataloguing or topic focus arenas. Another area of success in ontologies appears to be in business process expression languages. These ontologies exist and serve as benchmarks for what can be done, however the success of one particular ontology can seldom be used to infer much about the success of another one.

Standards: OWL is now a standard, submitted for approval by the WWW board on 18 August 2003. OWL is fully compatible with RDF[2], and RDF parses under OWL, and OWL scripts can be read into RDF. OWL forces graphs into trees that may not always be the most convenient representation. All these new tools add semantic modelling principles to XML.

Content Based Security Labelling: There are some interesting potential relationships between the XML schemas and the US led work on content based security labelling, (in which information objects are assigned some security value). A possibility for the future is rather than pre-assigned security classes, computable security values will be established which, depending upon the context of use, could be used to control security values and access/egress controls for various information exchanges.

Unified Modeling Language: An aspect that is not well covered is modelling, which is well represented as a capability by the OMG UML. Currently there is no formal link between UML[3] and OWL, but there appears to be a significant potential gain in being able to include complex process representations into OWL +UML (OWL++) format. This is because many of the key aspects of information exchange in a battlefield setting are process related, and take place in a time -critical setting. Notably target acquisition, targeting and interdiction.

Upper Level Ontologies: These are meant to represent high-level concepts that will range over a number of related ontologies. Obvious examples of ULO concepts are time, position, US view was that at this stage of the game that upper level ontologies (ULOs) are of little value, and the time spent on their development is a waste of time.[4]

Sample Data: Some examples of data tagging over a wide range of source material have been undertaken by IBM, and their results from over a million web pages, can be accessed on their web site.

Weak areas: Those needing further development include multimedia search and other non-text sources (e.g. *Google* is poor in this area).

Mark-up Support Tools: Mark-up support tools that allow a substantial degree of automatic mark-up of input material are available, but their scope is limited. Unfortunately much more complex schemas require human intervention. COTS mark-up schemas when executed need considerable human parsing to give effective results. A number of these products have been evaluated by the US.

The view is that current market products are not yet satisfactory, but that the prototypes currently in a number of US laboratories represent a major step forward, and that these will be in the market place within 2 years (2005 – 2007).

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[2] RDF = Resource Description Framework.

[3] UML = Universal Modelling Language.

[4] The IEEE is host for the development of an upper level ontology.

3.5 WAY FORWARD

3.5.1 General

Overall despite the many questions still facing the developers of ontologies for military and civil system problems, there is a very strong optimism within the research community. This is based on their experience with both realistic problem solving, and the successes in developing and applying ontology description languages, as epitomised by OWL. Substantial further steps in information management and exchange can be achieved by following and exploiting this new work. Nonetheless it is useful to note that this optimism still has its doubters [10, 11].

3.5.2 Way Forward for NATO

NATO is increasing in size, and increasing in heterogeneity. The developments in information exchange technologies reviewed in this workshop indicate that for NATO there are many benefits in seeking to develop a series of key interoperability models that can be implemented as compact ontologies that can be used across several, or all NATO nations.

These key thrusts are:

- Understanding, and advocating a favoured information exchange architecture;
- Developing a suitable interchange model;
- Understanding the limitations of that model; and
- Developing a baseline of very simple interchange architectures for ad hoc interoperability.

These developments require the realisation that heterogeneous systems are inevitable, so that a compact, efficient way is needed to deal with this. A coalition programme on selected interoperability topic areas would be a good starting point.

Chapter 4 – LESSONS LEARNED

4.1 PLANNING AND CONDUCTING WORKSHOPS

A major part of the work programme of the TG was to run a workshop in year 2. This was kindly hosted by France, and attracted a wide range of papers, and attendees from the participating countries. The workshop was run in two streams – ontologies and information architectures. Some useful lessons learned from this included:

- Workshop Programme Themes: The group spent some time developing the workshop themes, and in the event it was felt that this was time well spent.
- Stream Rapporteurs: It is important in workshops to have active rapporteurs to keep the discussion on-theme, and to arbitrate in the more intense discussions, and of course to collate and collect primary points and conclusions. For this last role it is also important to have someone, of reasonable technical competence to take notes, since rapporteurs are usually directly involved with discussions and cannot keep full notes.
- Papers for the Sept-04 Symposium: One of the objectives of the workshop was to solicit papers for the Sept-04 symposium. This process did not work particularly well, although the TG did provide three good papers into the Symposium. A *Lesson Learned* is that it is very difficult to direct the themes of, and contributions of papers for any symposium!
- Presentations -v- Discussion: Attendees at Workshops often wish to present set-piece presentations at workshops, and the TG’s workshop was no exception. We had to impose quite strict rules on the number of, and time allocation of such presentations to keep the sessions on track, and to encourage discussion, rather than instruction. This is most important for a successful workshop.
- Workshop Output: Each rapporteur was tasked with producing a write up of the main points from their streams, and this was done. A CD of all presentations and related material was issued as a CD ROM 8 weeks after the Workshop.

4.2 LIAISONS

Liaisons were primarily with National work on the TG topics via the TG members. Briefing on related activities was provided by some inputs at the Workshop (see section 4.1) and a presentation was given to the TG by Bert van Domsellaar on the work of the NATO C3 HQ group.

4.3 WORK METHOD AND COMMUNICATION MEANS

Work method was by various studies within each participating member, and reviews and debates at the TG meetings. Extensive interchange of information was made via e-mail during the conduct of the TG.

Chapter 5 – CONCLUSIONS AND RECOMMENDATIONS

5.1 GENERAL CONCLUSIONS

This chapter provides the overall conclusions on the TG work, including both some general conclusions and a summary of technical conclusions. The conclusions are aimed at the R&D community and the NATO operational community.

Information management is a central **unsolved** issue for NCW and NEC types of systems of systems. Despite this the degree of attention being given to this topic in some nations in not as strong as its importance should imply. In the work of the group, no experimental topics were pursued, since this was deemed to be premature, in terms of the **collective** capabilities of the TG participants' nations activities.

5.2 TECHNICAL CONCLUSIONS

The TG members believe that the issues of information domain architecture and the development of suitable and developable representational schemas are both of immense importance in getting to grips with the military information management problem. Serious issues that need to be better understood include:

Scaling: how much more complex does a system become when its scope is doubled, tripled etc in size. At present we simply do not know.

An agreed process for defining Domains and their interactions: This is the brief of the first ET proposed as follow-on activities, and requires both technical and military expertise.

Process representation: One important aspect of this is to better capture information and human processes that underpin information management and use. These are presently not well represented either in current data models, or in the representational schemas of the semantic web.

Security: In complex schemas such as the JC3IEDM, it is important too ensure that the various constructs used are compatible with security policy. It seems clear that for the semantic web, new concepts of security will be needed, although there appears to be little work on this, other than the US sponsored work on *label based security*.

5.3 RECOMMENDATIONS

5.3.1 Basic Recommendations

The TG has concluded that a further phase of study of the topic of Coalition Information Interoperability studies are well worthwhile, and has concluded that the best way to take this forward is via two separate TGs:

- One on Architectures; and
- One on Ontologies.

It is proposed to achieve this by formally terminating the TG010, Coalition information Interoperability, and establishing two exploratory teams, to define the programmes for architecture and ontology TGs, these ETs to commence in early 2005.

5.3.2 Style of Work

It was agreed by the TG members that any follow on work should have a good degree of practical / experimental work to better understand the limits and capabilities of theses methods.

5.3.3 Liaison

In view of the importance of the MIP IEDM programme, it is essential that these ETs have liaison links with the MIP programme.

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14. Abstract

This report provides a general and high level description of the activities of NATO RTO IST-028/ RTG-010, Task Group on Coalition Information Interoperability. The main objectives of the TG were to identify major needs and potential technical solutions to provide information interoperability across NATO coalitions, and with other Non-Government Organisations (NGOs). The work developed along two related but distinct lines, firstly investigating the potential value of ontologies for describing military situations, and secondly using a structured data model approach.

The primary results of the work were described in two major events, the first a Workshop held in Paris in November 2003, and with substantial international academic and military specialist support, and the second a NATO IST sponsored International Symposium, held in The Hague, 23-25 September, 2004.

This report provides a summary description of these activities, the group's major conclusions and its recommendations for further work in this important interoperability area.

For example a much more focussed investigation on ontologies is needed. Since the objective is to improve coalition interoperability, this needs to be undertaken as a multi-national programme. In this report some of the results and conclusions from the TG are explained in more detail and some of the major problems illustrated.

The second aspect was to look in Data Model Structures. The group's work was led by inputs from the TNO-FEL Netherlands.

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